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Myoelectric Prosthetic Arm Motion (Wrist/Hand) Control System

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***Abstract*— In India most of the people lost their hand due to road accident, disease and soldiers lost their arm in war. This paper describes the design which controls the hand motion and wrist motion of Myoelectric controlled prosthetic arm using cortex M3 microcontroller. In this design electromyogram signals are generated by contracting the muscles of biceps and sensed by electrode sensors. Electrode sensors produce the electrical signals and these signals are processed by microcontroller and achieve the supination motion from 0^0 to 75^0 and pronation motion from 0^0 to 85^0 in the wrist of hand[1][2].**

***Index Terms*—Bio control, Prosthetics, EMG signals, ARM Processor, Supination and Pronation motions, Electrode sensors.**

I. INTRODUCTION

In Today's era of medical field, mechatronic systems are playing the great role in human's life includes mechanical, electrical, electronics and computer modules [8]. Prosthetics is a great example of mechatronic system in biomedical field which is replaced with human's defective body part using rehabilitation techniques. This paper describes myoelectric prosthetic arm motion control system. In existing Myoelectric arm, the opening and closing of hand is controlled by sensing and processing the EMG-electromyogram signals generated when muscles are contracted.EMG signals are sensed by the electrode sensors, placed at edges of elbow joints. **Electromyography** (EMG) is a medical technique for measuring muscle response to nervous stimulation.EMG is performed using an instrument called an electromyography, to produce a record called an electromyogram. An electromyography detects the electrical potential generated by muscle cells when these cells contract [3]. The existing design has only opening and closing movement of hand but wrist movement is not available. This paper describes the design which integrates mechanical, electrical, electronics and biological systems and achieves the wrist motion (supination /pronation) and synchronization between hand motion and wrist motion using cortex m3 microcontroller.

II. ANATOMY OF HUMAN BODY AND ROBOT

Anatomy means identification and descriptions of structures of living things. The industrial robots resembles the human arm in it physical structure. Like the hand attached to the human body the robot manipulator or robot arm is attached to the base. The chest, the upper arm and fore-arm in the human body compare with links in the robot manipulators.

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Anatomy of robot is shown in Fig. 1.The wrist, elbow and the shoulder in the human arm is represented by the joints in robot arm and chest, fore-arm and upper arm is represented by the links and body is represented by the base. The drivers or motion to the links is provided at the joints. The joints motions can rotational or translator [4].

The wrist is complicated joint in order to maintain the mobility of hand without sacrificing the stability that bridges the hand to the fore-arm. It is actually collection of multiples bones and joints. The human hand is capable of 3 degree of freedom, first is flexion and extension, second is pronation and supination and third is adduction and abduction. As per the human body's anatomy, the pronation, supination, flexion and extension movement angles of wrist are 0^0 to 85^0, 0^0 to 75^0, 0^0 to 75^0 and 0^0 to 70^0 respectively. This paper explain the analytical description of motion geometry of the Myoelectric arm with references to a robot co-ordinate system fixed to a frame, without consideration of the forces or the moments causing the movements. The motion is described as a function of time. [5]

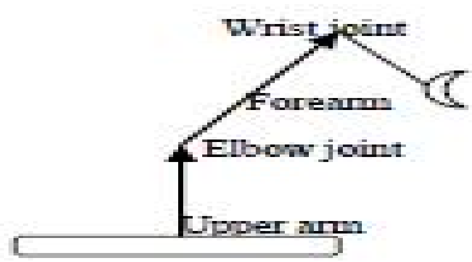

Figure 1. Anatomy of Robot

III. DESIGN AND METHODOLOGY

The relation between the body attached frames with the base frame of references is described by the transformation matrix. The transformation is represented by the rotation matrix, position vector, and perspective transformation and stretching. Let body attached reference frame be represented by OABC as shown in Fig. 2 and the base reference frame be OXYZ. Let the position vector with respect to OABC be P_{ABC} and the same point P has vector representation in the OXYZ frame be P_{XYZ}.The vector P_{ABC} is $P_a\ i_a + P_b\ i_{b+}\ P_c\ i_c$ and vector is P_{ABC} is $P_x i_x + P_y i_Y + P_z i_z$.The co-ordinates of the point P in the two frames are $P_{ABC} = (P_a, P_b, P_c)^T$ and $P_{XYZ} = (P_x, P_y, P_z)^T$. The two vectors are related by a rotation matrix 'R' as to $P_{XYZ} = RP_{ABC}$.[4]

A. Rotation abot x-axis

To develop a relation for the rotation matrix R(x,α), the body attached co-ordinate system OABC is rotated about OX of the base co-ordinate system by an angle α, which is represented by the diagram Fig. 3.

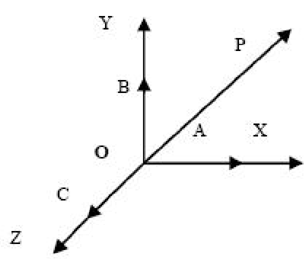

Figure 2. Co-ordination representation

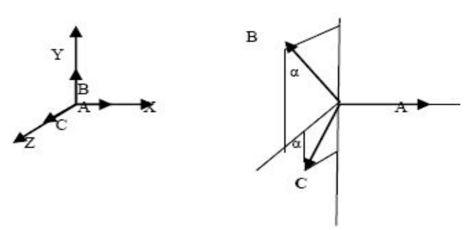

Figure 3. Rotation about x-axis

It is evident from the Fig. 3 that

$$P_x = P_A + 0(P_{B)} + 0(P_{c)}$$
$$P_y = 0(P_{A)} + P_B.\cos\alpha {}_+ P_c.(-\sin\alpha) \quad (1)$$
$$P_z = 0(P_A) + P_B.\sin\alpha + P_c.\cos\alpha$$

"Equation (1) can be expressed in matrix form as"

$$\begin{pmatrix} P_x \\ P_y \\ P_z \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} P_A \\ P_B \\ P_c \end{pmatrix}$$

$$P_{xyz} = R(x,\alpha).P_{ABC} \qquad (2)$$

B. Rotation about y-axis

The Fig. 4 Shows the vector P_{ABC} being rotated by an angle β about the OY axis of the OXYZ base co-ordinate system. The expression for the rotation transformation matrix, R(y, β) can be obtained from the following equations [4].

$$\begin{aligned} P_x &= P_A.\cos\beta + P_B(0) + P_c.\sin\beta \\ P_y &= P_A(0) + P_B.(1) + P_c.(0) \\ P_z &= P_A(-\sin\beta) + P_B(0) + P_c.\cos\beta \end{aligned} \qquad (3)$$

The rotation matrix is

$$R(y,\beta) = \begin{pmatrix} \text{Cos}\,\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{pmatrix}$$

$$Pxyz = R(y,\beta).P_{ABC} \qquad (4)$$

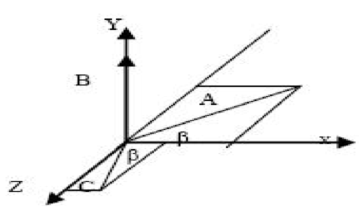

Figure 4. Rotation about y axis

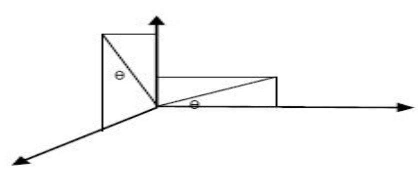

Figure 5. Rotation about z axis

C. Rotation about z-axis

The OABC frame is rotated about an angle θ about the oz-axis of the base frame OXYZ. The position vector P_{xyz} has its components derived out the vector P_{ABC} as shown in Fig. 5.

$$\begin{aligned} P_x &= P_A.\cos\theta + P_B(-\sin\theta) + Pc.(0) \\ P_y &= P_A.\text{Sin}\,\theta + P_B.\cos\theta + P_c.(0) \\ P_z &= P_A(0) + P_B(0) + P_c.(1) \end{aligned} \qquad (5)$$

"Equation (5) can be expressed as"

$$\begin{pmatrix} P_x \\ P_y \\ P_z \end{pmatrix} \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} P_A \\ P_B \\ P_C \end{pmatrix}$$

$$P_{xyz} = R(z,\theta).P_{ABC} \qquad (6)$$

D. Pronation and supination motions equation implementation

In design motor rotate about only x-axis. The equation to find out the co-ordinates for supination and pronation motion in wrist is

$$R(x,\alpha) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & -\cos\alpha \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$$

For 85^0 pronation movement, α angle is 85^0 about x-axis.

$$T = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos85 & -\sin85 \\ 0 & \sin85 & \cos85 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & .0871 & -.9961 \\ 0 & .9961 & .0871 \end{pmatrix}$$

The Co-ordinates points are 7, 5, 3, which are rotated about the about x-axis by angle 85^0.

$P_w = T.p_t$

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & .0871 & -.9961 \\ 0 & .9961 & .0871 \end{pmatrix} \begin{pmatrix} 7 \\ 5 \\ 3 \end{pmatrix} = \{7, -2.55, 5.25\} \qquad (7)$$

The co-ordinates 7, -2.55, 5.25 are out on ports of microcontroller to achieve the 85^0 pronation movement in wrist

For 75^0 supination movement, α angle is 75^0 about x-axis.

$$T = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos75 & -\sin75 \\ 0 & \sin75 & \cos75 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & .0871 & -.9961 \\ 0 & .9961 & .0871 \end{pmatrix}$$

The Co-ordinates points are 7, 5, 3, which are rotated about the about x-axis by angle 75^0

$P_w = T.p_t$

$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & .2588 & -.9659 \\ 0 & .9659 & .2588 \end{pmatrix} \begin{pmatrix} 7 \\ 5 \\ 3 \end{pmatrix} = \left[7, -1.6, 5.6 \right] \quad (8)$$

The co-ordinates 7, -1.6, 5.6 are out on ports of microcontroller to achieve the 75^0 supination movement in wrist.

E. LPC1769 based motion control system

Fig. 6 shows the block diagram of myoelectric prosthetic motion control system. Tilt sensor first senses the movement of elbow in up direction and output of tilt sensor (Electrical signal) is given to amplifier to amplify the signal. After amplification of signal, Inbuilt ADC converts the electrical signal into digital signals and then digital signal is processed by LPC1769 cortex-M3 microcontroller and controls the wrist motion. The point on the surface of the skin overlying a muscle at which the smallest amount of current activates the muscles is called motor point. Electrodes are placed over these points in order to achieve maximal muscle stimulation with minimal current. The position of electrode is gradually shifted until the maximum muscle contraction is obtained at the fixed level of stimulation [5]. In existing Myoelectric arm wrist motion is passive, controlled by the user and synchronization between hand and wrist motion does not exist. This design achieves the synchronization between hand motion and wrist motion. The design consists of LPC1769 cortex M3 microcontroller, Wrist motion and hand motion drivers, Tilt sensor, amplifier and power supply section. The LPC1769 is ARM Cortex-M3 based microcontrollers for embedded applications featuring a high level of integration and low power consumption. The ARM Cortex-M3 is next generation core that offers system enhancement Such as enhanced debug features and a higher level of support block integration. The LPC1769 operates at CPU frequencies of up to 100 MHz. The LPC1769 operates at CPU frequencies of up to 120 MHz. The ARM Cortex-M3 CPU incorporates a 3-stage pipeline and uses Harvard architecture with separate local instruction and data buses as well as a third bus for peripherals. The peripheral complement of the LPC1769 includes up to 512 kB of flash memory, up to 64 kB of data memory[6][7][8].

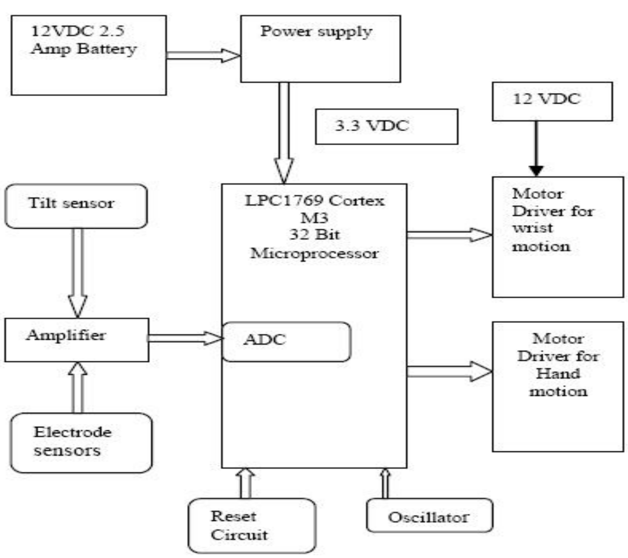

Figure 6. Block diagram of proposed system

RESULT

This design successfully achieves the wrist motions in myoelectric prosthetic hand with supination movement from 0^0 to 85^0 angle and pronation movement from 0^0 to 85^0 angle [9][10].

CONCLUSIONS

From above result it is conclude that microcontroller based motion control system is designed in such way that synchronization between hand motion and wrist motion achieves at desired degree.

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